# Fermilab

Radiation Physics Note No. 27
J. D. Cossairt
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## Thyac vs. Elron: Detection of Low Levels of Radioactivity

At Fermilab, two portable instruments are commonly used to determine if a suspected item is radioactive. These are the "Thyac" which uses a NaI crystal (1" x 1" cylinder) to detect decay gamma rays and the "low range Elron" (also, more correctly, called the "rotary switch Elron") which uses a Geiger-Muller (GM) tube to detect decay gamma rays. Both instruments are designed and calibrated for detecting gamma rays. The Elron responds with poor efficiency to β rays while the Thyac is well shielded from all quanta emitted in radioactive decay except photons, therefore the Thyac has an intrinsically lower background counting rate than does the Elron. It should be emphasized here that the so-called "high range" or "push button" Elron is totally unsuitable for use in detecting low levels of radioactivity because its low range scale reads no lower than 1 mR/hr while the natural background measured with the rotary switch Elron is typically 0.03 mR/hr.

A brief comment should be made here concerning energy response. The detection efficiency of NaI crystals similar in size to the one in the Thyac, typically decrease by a factor of 5 to 10 between 0.1 and 2 MeV photon energy[1)] (the efficiency below 0.1 MeV is essentially flat). On the other hand the specifications for the GM tube in the Elron indicate correct reading for a side exposed tube within ±20 percent over the photon energy domain from 0.06 to 1.3 MeV. A front exposure of the Elron GM tube would be expected to exhibit an overresponse to photons less than 100 keV[2]. Finally it should be stated that the so called "snoop" Thyac (the version having a switch selectable GM probe in addition to the NaI) is purposely designed to overrespond relative to the "regular" Thyac[2]. Figure 1 is a plot of Elron mR/hr reading as a function of Thyac counts/minute reading at the same location. Measurements were done in radiation fields of different magnitudes from gamma ray sources in order to determine the relative response of the two instruments. These results are displayed on Fig. 1 along with results from various activated items found in the Accelerator Cross Gallery, all of which had been cooling off for several months (removing short-lived activities including $\beta$-emitters) described in Table 1. The solid line is a least squares fit to the data from the radioactive sources and has the equation:

$$\text{Elron (mR/hr)} = 9.43 \times 10^{-6} \text{ Thyac (counts/min)} + 6.43 \times 10^{-4}$$

The intercept is thus insignificant and the slope indicates that approximately 10000 counts/min (Thyac) implies an exposure rate of 0.1 mR/hr (Elron) for the sources used:

$^{137}Cs$: $E\gamma = 0.66$ MeV
$^{60}Co$: $E\gamma = 1.34, 1.17$ MeV
$^{22}Na$: $E\gamma = 0.511, 1.27$ MeV

The dashed lines enclose discrepancies as large as ±30 per cent and include most of the data. Near the origin the cross-hatched area indicates the region defined by the natural background of both instruments which is approximately 0.03 mR/hr (Elron) and 1500 counts/minute (Thyac). The Thyac background, from the data presented here, indicates an exposure rate background of 0.015 mR/hr or a factor of 2 enhanced sensitivity relative to the Elron. It should be pointed out that in fields greater than 1 mR/hr, the Thyac will underrespond relative to the Elron due to saturation of the circuitry[2]. It is important to note that the Elron background is based on far fewer counts in the detector. One mR/hr with the Elron probe corresponds to 1500 events/min in the GM tube so that 0.03 mR/hr implies 45 events/min so that the standard deviation in the event rate is 6.7 events/min implying 15 per cent fluctuations at one standard deviation. For the Thyac the event rate in the NaI crystal is 10000 events/min implying 1 per cent fluctuations at one standard deviation. The statistical fluctuations are thus much larger and more care by the user is required to determine if a reading is "above background" using an Elron.

An important item which needs consideration is the specific activity in an accelerator produced object needed to produce a measurable reading on these instruments. This is an important consideration in view of the necessity to prevent unauthorized transport of radioactive material off-site. For purposes of this note "twice background" will be the criterion used as the limit of detectability for both instruments. The background reading will be that mentioned above. Local backgrounds will vary and will usually be higher than the ones used here so that the detectability limits will be affected accordingly.

In Ref. 3, an estimate of the specific activity (S.A.) of Main Ring magnets from measured exposures rates (measured with an Elron) was made. From that paper it is easily seen that: (including background in the readings) but not including any safety factors,

$$0.06\ \frac{\text{mR}}{\text{hr}}\ \text{(Elron)} \Rightarrow \text{S.A.} = 7.9 \times 10^{-10}\ \text{Ci/gm}$$

for such a magnet measured externally at a distance of 30 cm. From the above curve:

3000 counts/min (Thyac) => S.A. = $3.9 \times 10^{-10}$ Ci/gm

The same paper also indicates that a measurement down the bore of a magnet with a GM tube instrument would give:

0.06 mR/hr (Elron) => S.A. = $7.9 \times 10^{-12}$ Ci/gm

The Thyac probe will not fit down the bore of most Fermilab magnets but the obvious scaling would apply in cases where it would fit. Also, other bending magnets used in high energy hadron (E>1 GeV) beam would have similar results. In another situation, described in Ref. 4 an RF cavity was treated similar to the magnet treated in Ref. 3. In that case (again including background in the readings without any safety factors):

0.06 mR/hr (Elron) => S.A. = $5 \times 10^{-11}$ Ci/gm

while

3000 counts/min (Thyac) => S.A. = $2.5 \times 10^{-11}$ Ci/gm

for the probes held 30 cm from the side of the cavity. These two examples present roughly the threshold of detectability for two large items; one very dense and the other relatively thin, but both relative large in physical size.

Admittedly, both objects represent targets in the Fe mass region. However, the results shown in Fig. 1 indicate this is typical of various objects activated at Fermilab. It is clear that either instrument can be used to detect low levels of radioactivity with the Thyac having a definite edge in sensitivity. Both instruments are really designed only for gamma emitters and the Thyac would miss $\beta$ emitters entirely while the Elron would be only very weakly sensitive to them.

References:


1. J. B. Marion and F. C. Young, Nuclear Reaction Analivis Graphs and Tables, (North Holland, 1968).

2. F. P. Krueger, private communication.

3. J. D. Cossairt, Radiation Physics Note #22, "Magnet Activation Calculation," May, 1979.

4. J. D. Cossairt, Radiation Physics Note #23, "Calculation of Specific Activity for a PPA RF Cavity," May 1979.

Table I

Various Activated Items Shown on Fig. 1 (all measured in accelerator galleries in low background areas.)

A. Large ion pump.

B. Helium leak detector.

C. Power amplifier.

D. Radioactive material cabinet (contents unknown).

E. Golf cart.

F. Main ring 10 foot quadrupole measured along the side.

G. Same as F only measured at the entrance to the bore.

H. Superconducting ES quadrupole measured along the side.

I. Same as H only measured at the entrance to the bore.

J. Main Ring magnet stand.

K. Main Ring beam pipe (30 foot long piece).

L. Turbo pump.

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